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CHAPTER 18

CABLE PERFORMANCE

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1. INTRODUCTION

Cable failure reporting in the United States had its beginning by action of the Edison Electric Institute and its predecessor the National Electric Light Association. A significant early report covered the performance of paper insulated, lead covered cables, splices, and terminations beginning in 1923. Failure rates of cable were reported in units per 100 installed miles for a variety of causes. Splice and termination reports were based on failures per 1000 units that were in service. These reports were continued through 1966 and served both as a useful performance guide as well as a barometer of the effectiveness of the cable specifications in effect. The National Electric Light Association prepared the first U.S. paper cable specification in 1920 for cables rated up to 15 kV. The Association of Edison Illuminating Companies upgraded this to 45 kV in 1930.

The advent of underground residential distribution (URD) systems with the extensive use of extruded dielectric cable convinced the U.S. utility group to become involved in specifications for this evolving type of cable. Later usage in conventional urban duct and manhole systems to take the place of the backbone paper insulated cables finalized this requirement.

During the early 1970s, isolated reports of early cable failures on the extruded dielectric systems began to be documented in many parts of the world. "Treeing" was re-introduced to the cable engineer's vocabulary, but with an entirely new meaning from the paper cable use of the word.

The Edison Electric Institute's last attempt to report distribution cable failures was in 1973. A vacuum was therefore developed in the U.S. for distribution cable failure reporting. No system for similar reporting existed in the world.

2. CABLE FAILURE DATA

The data coming from a few U.S. utilities and work funded by EPRI by 1975 [18-2] showed that thermoplastic polyethylene insulated cables were failing at a rapidly increasing rate and that XLPE and EPR cables had a lower failure rate.

The next compilation of data began in 1976 with 16 and later 21 utilities in North America reporting their failure rates on an annual basis for both polyethylene and crosslinked polyethylene insulated cables [18-3].

Failure data kept by the utilities was rather meager. It was decided to only request data based on type of insulation, number of failures for each year and the total amount of each of those insulation types were in service at the end of the year. It was also decided to only ask for failures of known electrical causes, such as defective cable, insulation deterioration, lightning, etc., and then include all "unknown" causes since treeing analysis was not easily obtainable.

3. PERFORMANCE

Comparable data from EEI for paper insulated, medium voltage power cables installed in the United States is included as Figure 18-1 for the years of 1923 through 1966 -- when the data was no longer collected. Similar data showing the electrical failures of polyethylene and crosslinked polyethylene for 21 North American utilities is shown in Figure 18-2. AEIC then began to collect and report similar data in 1984 except that data was requested from all utilities. A major future step was to request information on jackets, ducts, voltage stress levels, etc. The old 21 company base was not separately recorded, however. They also began to collect data for tree retardant XLP as well as EPR. See Figures 18-3, 18-4, 18-5 and 18-6.

AEIC strongly suggests that this data be carefully analyzed and understood. This is important since the age of the cables were not known and could skew the results. For instance, jacketed cable is probably newer than non-jacketed cable and hence the failure rate of the older cables may not be entirely the result of a jacket.

The European community also began to collect data and their results were published as UNIPEDE-DISCAB that represents most of the European countries. Their data includes PE, XLP, EPR and PVC.

4. ANALYSIS OF DATA

Cable failure rates in the U.S. have historically been calculated on the basis of failures per 100 miles of installed cable. The rest of the world reports failures per 100 kilometers. All data is shown as rates per 100 miles for ease of comparison.

The most frequently used form for the data shows the number of failures per 100 miles for each year. The disadvantage of such depiction is that older cable is

looked at in the same light as new cable. This data is more readily available, but a preferred method is to take into account the years in service for all cables. This is accomplished by integrating the miles installed with the years of service. The expression is :

$$\text{Service Index } A_j = \sum i (M_i N_{j-i}) \quad (18.1)$$

where A = system age in year j in terms of service mile-years,
 M_i = the number of miles of cable installed in year i ,
 N_{j-i} = the number of years from i to j .

<u>Years</u>	<u>Miles of Cable Multiplied by Age</u>				
A	a				
B	2a	b			
C	3a	2b	c		
D	4a	3b	2c	d	
E	5a	4b	3c	2d	e
F	6a	5b	4c	3d	2e f, etc.

At the end of the year F, the age of the system is:

$$A_F = 6a + 5b + 4c + 3d + 2e + f \quad (18.2)$$

where a, b, c , etc. represent the number of miles of cable installed in year A, B, C....

This analysis can be shown as a summation of failures per 1,000 mile-years, this is:

<u>Year</u>	<u>Cumulative Miles of Cable at End of Year</u>	<u>Summation</u>
A	a	a
B	b	a + b
C	c	a + b + c
D	d	a + b + c + d
E	e	<u>a + b + c + d + e</u>

$$\Sigma = 5a + 4b + 3c + 2d + e$$

It is only necessary to add the miles of cable installed each year to the summation of cable installed in all previous years to obtain updated mile-years

from this equation.

5.0 PRESENT SITUATION

There is no new data to report regarding cable failure statistics. This is the result of two factors:

- ☐ New cable performance is very good. The few problems with new cable makes collecting data seem unnecessary.
- ☐ There are not enough people to do the essential work.

The last North American data was collected for 1991 performance by AEIC. The data shows an extremely low failure rate for TR-XLPE and EPR. The XLPE rate is not escalating to a troublesome level. The European collection of data has also been discontinued.

This is certainly an indication of the effort that has been directed toward improved cables - both from the material suppliers standpoint as well as the cable manufacturers.

Figure 18-1
PILC Cable Failures in the United States

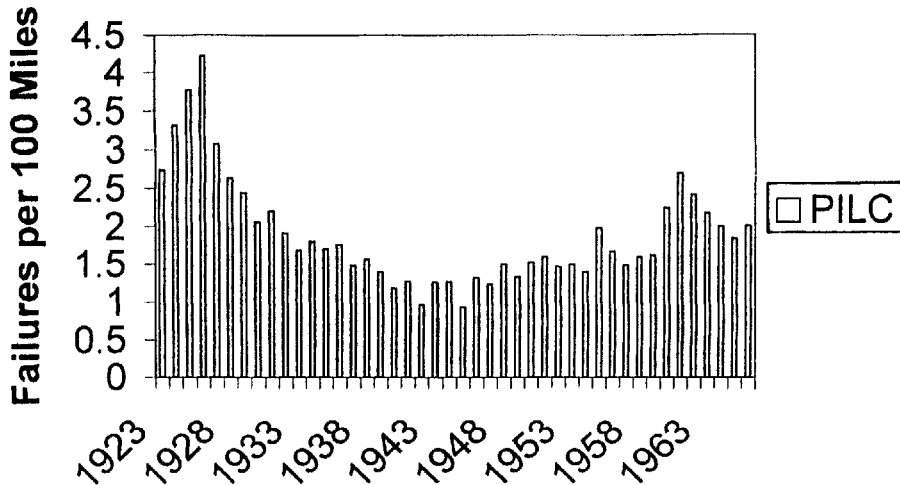


Figure 18-2
Electrical Failures of Extruded Dielectric Cables

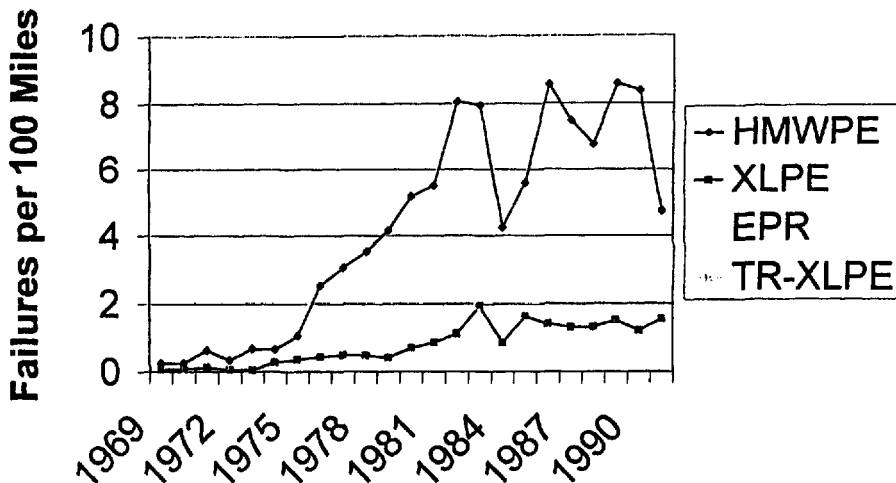


Figure 18-3
AEIC Cable Failure Data, High and Low Electrical Stress

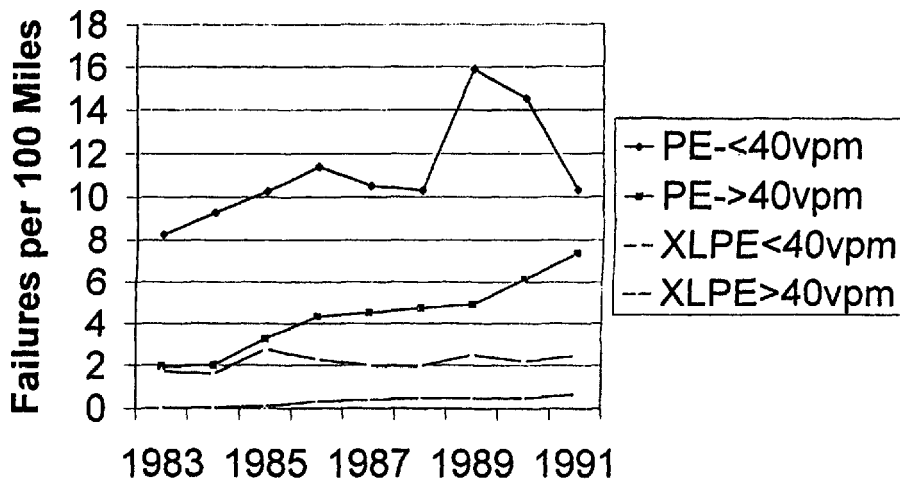


Figure 18-4
AEIC Cable Failure Data, Duct versus Direct Buried

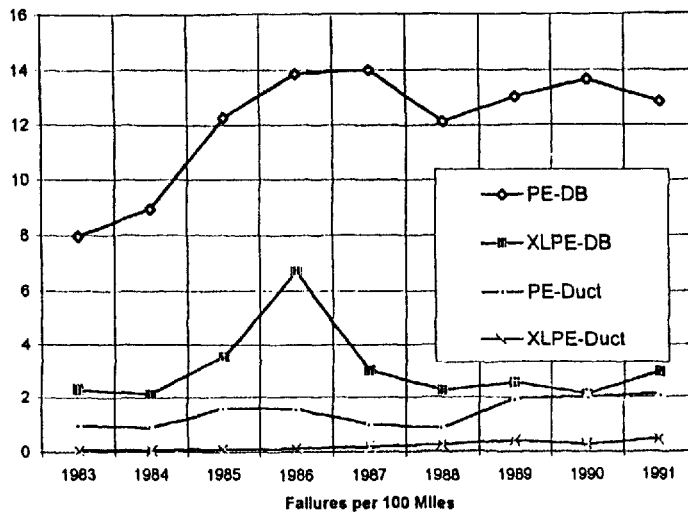


Figure 18-5
AEIC Cable Failure Data, Jacket versus Non-Jacket Construction

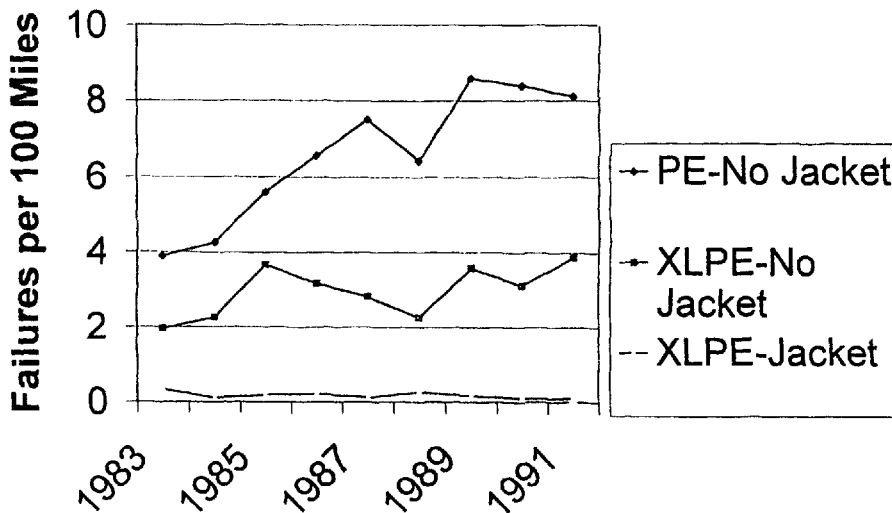
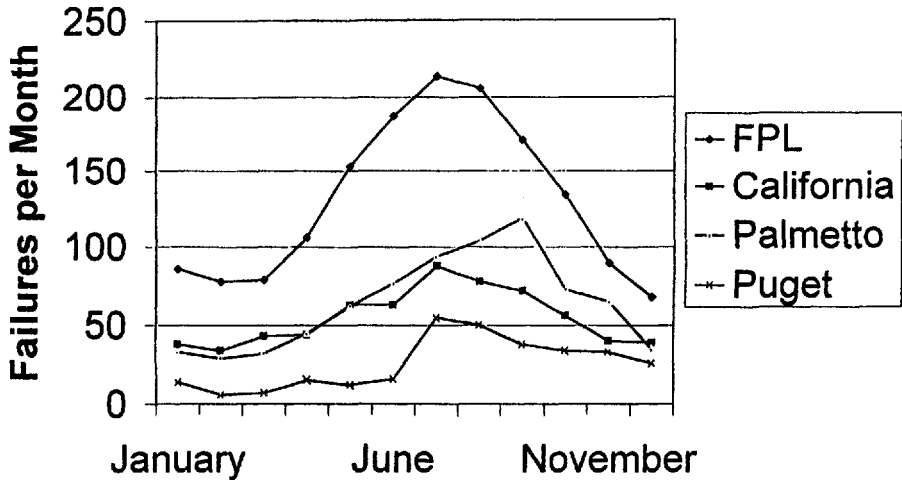


Figure 18-6
Cable Failure Data, Seasonal Pattern



6. REFERENCES

- [18-1] W. A. Thue. Adapted from class notes, Power Cable Engineering Clinic, University of Wisconsin – Madison, October, 1997.
- [18-2] EPRI RP 133: "Electrochemical Treeing in Solid Dielectric Cable," EPRI Report EL-647, 1976.
- [18-3] W. A. Thue and J. Bankoske, "Operating and Testing Experience on Solid Dielectric Cables," CIGRE, 1980.